Fisheries and Oceans Canada | Pêches et Océans Canada
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Maritimes Region
Canadian Science Advisory Secretariat
Science Advisory Report 2007/045

ASSESSMENT OF NORTHERN SHRIMP ON THE EASTERN SCOTIAN SHELF (SFA 13-15)

(J. Domm 2006)

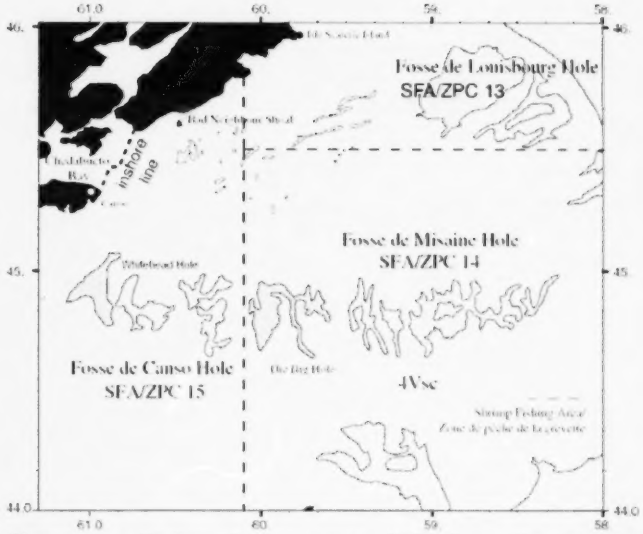

Figure 1. Shrimp fishing areas (SFAs) on the eastern Scotian Shelf.

Context

Advice on the status of the eastern Scotian Shelf shrimp stock is requested by DFO Fisheries and Aquaculture Management and industry to help determine a TAC that is consistent with the management plan. Annual assessments are required because of rapid changes in abundance, variable recruitment to the population and fishery, and changes in the size of shrimp available for harvest. The resource is near the southern limit of the species' distribution where it is thought to be more vulnerable to significant and rapid declines, as has been observed in the adjacent Gulf of Maine stock. The current report provides information and advice for management of the 2008 fishery.

The trawl fishery on the Scotian Shelf currently occurs primarily during late spring and early summer with some fishing during fall, in the deep offshore shrimp "holes", and on an inshore area near the Bad Neighbor Shoal. The main management tools are limits on the number of licenses and size of vessels used, minimum codend mesh size (40mm), use of a Nordmøre separator grate, and a Total Allowable Catch (TAC). This fleet (about 20 active trawlers) is divided into two sectors, a midshore sector consisting of about 7 active vessels 65-100' Length Over all (LOA) based in New Brunswick on the Gulf of St. Lawrence side, and an inshore sector consisting of vessels mainly <65' LOA based on the Atlantic coast of Nova Scotia. A trap fishery, consisting of 2-7 active vessels is restricted to Chedabucto Bay. All licenses except traps operate under Individual Transferable Quotas (ITQs). Stock assessments are conducted annually based on indicators from commercial, scientific survey, and environmental monitoring data.

Canada

SUMMARY

- A decrease in biomass (16%) was observed in Stratum 14 (Misaine); however, this was offset by increases in other areas, resulting in little change from 2006. The DFO-industry survey index remains higher than the long-term average.
- The 2007 SSB (spawning stock biomass of females) was also similar to 2006 and remains about average. SSB and total biomass are expected to stay at a similar level in 2008 as the large 2001 year-class continues to change sex.
- Commercial catch rates (CPUEs) have been fluctuating at a high level since 2002.
- Effort continued to shift to SFA 14; however, exploitation rates were relatively evenly distributed across areas.
- Fishers have experienced difficulty in avoiding small shrimp from the 2001 year-class since 2005 and this will probably continue into 2008.
- Size at sex transition and maximum size have been decreasing for about 10 years.
- The 2001 year-class continues to be strong in all areas. It currently makes up about 70% of the biomass, which is a concern because of the unevenly distributed age structure and could accentuate the pulsed recruitment pattern that has developed.
- Total exploitation (11%) and female exploitation (14%) indices are just below average, but exploitation of the smallest (<19mm CL) shrimp increased to well above average in 2007, which is a conservation concern due to the lower recruitment in recent years.
- With biomass expected to remain relatively high, the TACs of the last two years should be sustainable in 2008.
- The 2002-2006 year-classes are weaker than the 2001 year-class. Total and SSB biomass will decrease after 2008, the rate of decline depending on the natural mortality and longevity of the 2001 year-class. TAC reductions may be necessary after 2008.

BACKGROUND

Species Biology

The northern or pink shrimp, *Pandalus borealis*, is the only shrimp species of commercial importance in the Maritimes Region. Shrimp are crustaceans, and have a hard outer shell which they must periodically shed (molt) in order to grow. The females produce eggs once a year in the late summer-fall and carry them, attached to their abdomen, through the winter until the spring, when they hatch. Consequently, shrimp bear eggs, or are "ovigerous" for about 8 months of the year. Newly hatched shrimp spend 3 to 4 months as pelagic larvae, feeding near the surface. At the end of this period they move to the bottom and take up the life style of the adults. On the Scotian Shelf, the northern shrimp first matures as a male, at 2 years of age, and at age 4 it changes sex, to spend another 1 to 2 years as a female. Shrimp live 5 to 8 years, depending on conditions.

Shrimp concentrate in deep "holes" on the eastern Scotian Shelf (Figure 1), but nearshore concentrations along coastlines closest to the offshore populations were discovered by 1998. They prefer temperatures of 2 to 6 °C, and a soft, muddy bottom with a high organic content.

The Fishery

The fishery currently consists of 28 (20 active) inshore licenses mostly <65' LOA and 7 active mid-shore licenses 65-100' LOA. All mobile licenses have been under ITQs since 1998. A competitive trap fishery with 14 (~2 currently active) licenses is restricted to Chedabucto Bay.

The fishery operates under a 5-year management agreement (2007-2011) which, among other aspects, documents sharing agreements between fleet sectors.

The TAC has been caught most years since individual SFA quotas were combined into a single TAC in 1994, with minor shortfalls associated with re-allocations of uncaught trap quotas to the mobile fleet late in the season (Table 1; Figure 2). More substantial shortfalls occurred in 2005-2007 unrelated to resource availability. The gap between TAC and catch has narrowed steadily since 2005 as logistic problems associated with market conditions and quota reallocations were resolved. Trap fishing effort and catches have decreased substantially since 2005 for economic reasons, but catches per trap haul remain good (~10 lbs/trap haul). The mobile fleet continues to prefer open access to all areas (i.e., no individual SFA quotas) because of the flexibility this offers in obtaining favourable combinations of good catch rates and counts (shrimp sizes).

Table 1. Recent shrimp TACs and landings (000s mt)

Year	2000	2001	2002	2003	2004	2005	2006	2007[1]
TAC	5.5	5.0	3.0	3.0	3.5	5.0	5.0	5.0
Landings	5.4	4.8	2.9	2.8	3.3	3.6	4.0	4.5

[1]Landings projected to December 31, 2007.

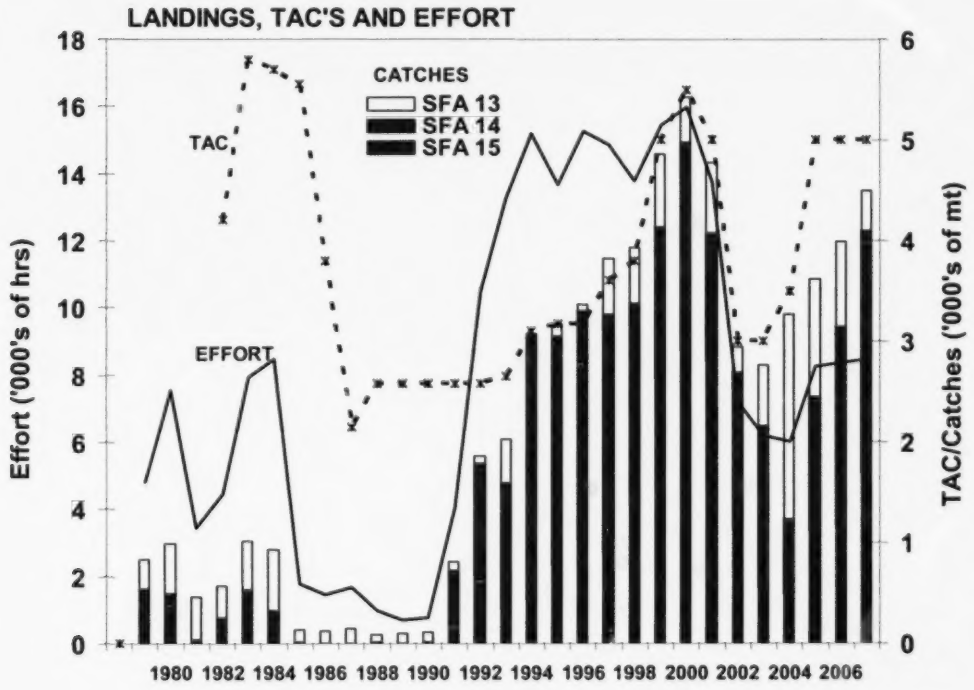

Figure 2. Landings, TACs and Effort.

The **temporal pattern** of the fishery has changed little over the years (Figure 3, left). Most shrimp are caught during April-June. Effort tends to decrease during summer due to market conditions. Catches during the August-April ovigerous (egg-bearing) period tend to increase when TACs increase as fishers take longer to catch higher quotas. This was the case in 2005-2006 when about 30% percent of the catch was taken during the ovigerous period, but this decreased to about 20% in 2007 as fishers took advantage of the good weather months. This is not currently considered to be a problem due to the large SSB, but it could potentially contribute

to other factors decreasing population fecundity, such as decreasing size at sex change and female sizes.

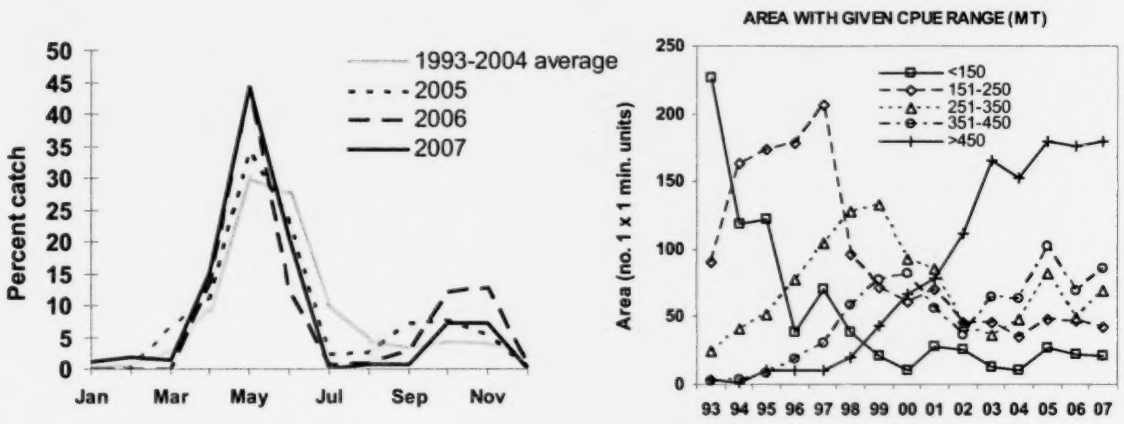

Figure 3. Temporal (left) and spatial (right) patterns in the Scotian Shelf shrimp fishery.

The **spatial pattern** of the fishery has changed significantly over the years reflecting changing distributions of biomass and size frequencies. Prior to 1999, most of the effort and catch was in the Misaine Hole (SFA 14). In 1998, fishing began along-shore near the Bad Neighbor Shoal, with 44% of the catch taken in this area during 1999. This decreased to only 4% in 2004, and then increased again to 24% in 2007. In 2004, a large part of the TAC (57%) was taken in SFA 13, but this declined to less than 1% in 2007 as effort shifted back to SFA 14 to take advantage of the large accumulated biomass there (50% of the catch in 2007). This has resulted in a relatively even distribution of exploitation rates across areas during the last 2 years. Spatial and temporal changes in the distribution of fishing effort, catch rates (Figure 3, right), availability to the fishing gear, and the resource itself are complex. Consequently, commercial catch per unit effort is not always representative of overall abundance as shown by the occasional divergence of CPUEs from DFO-Industry survey indices (Figure 6).

Decreases in the **average sizes of females** in the catch from 1997-2001 compared to the higher values of the early to mid 1990s (Figure 4, left) is due in part to the removal of accumulated older and larger animals in the population by the fishery, but decreased growth rates of the strong 1993-1995 year-classes were also involved. This trend has reversed in recent years as the survivors of these year-classes continued to grow and the weaker succeeding year-classes achieved larger sizes. Female size decreased in 2007 and it may decrease again as the slow growing 2001 year-class matures, but its final size depend on a combination of growth rate and longevity. An increasing trend in the **proportion of females** (Figure 4, left) caught from 2000-2004 occurred as males became less abundant and the 1993-1995 year-classes dominated the population and catch as females. This trend reversed in 2005-2007 as these year-classes died off and the strong 2001 year-class appeared in catches as males. **Count** estimates (numbers of shrimp per pound) provided by vessel captains increased significantly in 2005-2007 for the same reason (Figure 4, right). This indicates that many fishers had difficulty avoiding small shrimp from this year-class and maintaining counts below buyer limits to obtain the best prices. Some fishermen voluntarily switched to larger codend mesh sizes beginning in 2004, but this was ineffective in avoiding small shrimp during 2005-2007 as the 2001 year-class grew and dominated catches. Experienced captains have significantly lower counts, indicating that fishing skill is a factor. High counts and low prices continue to concern the fishery. Increased exploitation rates of the smaller sizes (<19mm carapace length) were considerably above average in 2007, which is a conservation concern considering the relatively low recruitment rates since 2001.

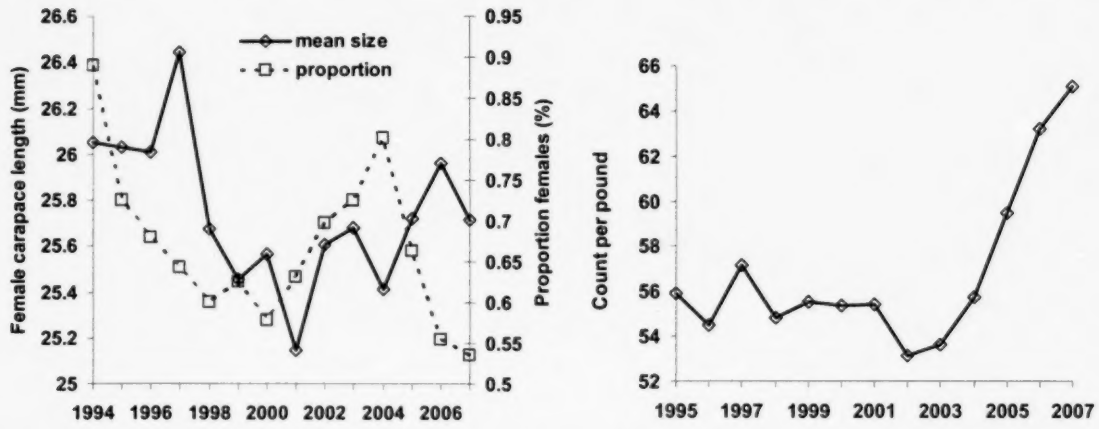

Figure 4. Mean female carapace length, proportion of females (left) and the count per pound (right) in the commercial shrimp trawl fishery.

The catch at length for 1995-2007 is shown in Figure 5.

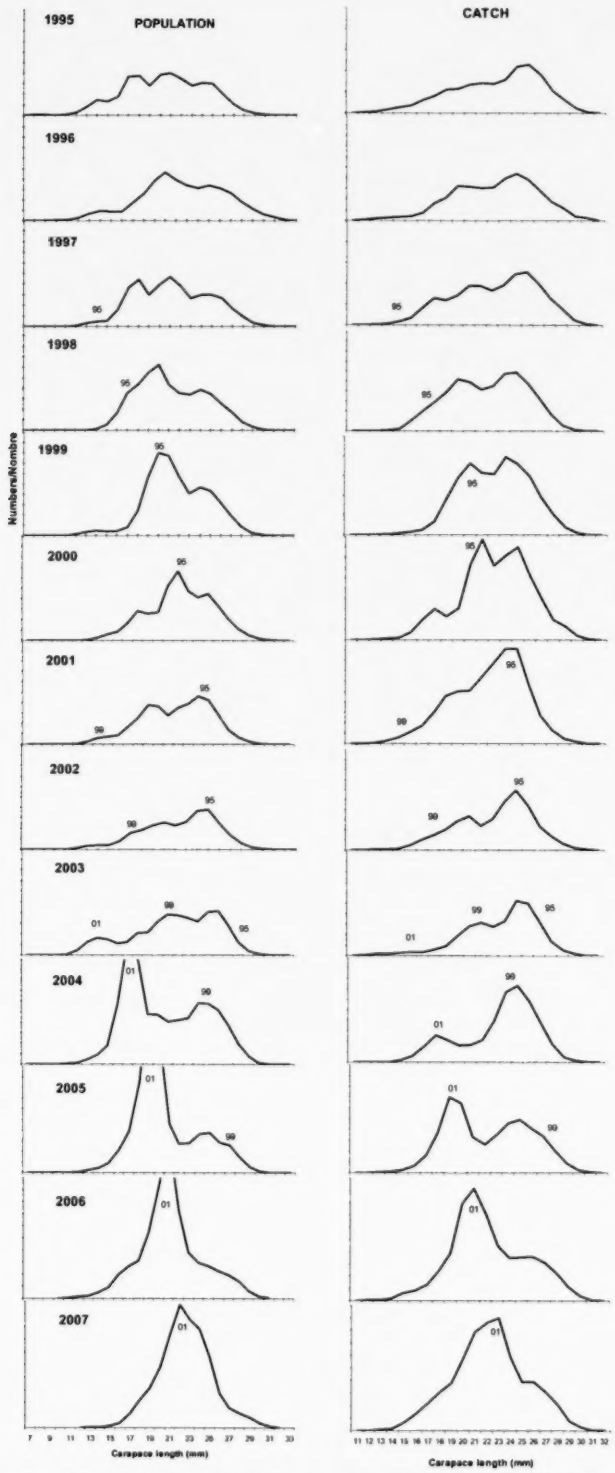

Figure 5. Survey population (left) and catch (right) at length estimates 1995-2007. The maximum value of each panel is $10*10^8$ and $10*10^7$ shrimp for the population and catch figures, respectively. Selected year-classes are identified in the population estimates.

ASSESSMENT

Stock Trends and Current Status

After a sustained long-term increase, commercial **CPUE** indices (Figure 6) leveled off and have been fluctuating at a high level since 2002. As indicated above, these indices probably do not reflect overall abundance changes in the short term due to changes in the spatial distribution of the resource and fishing effort, and in availability to the gear, but they presently appear to be indicative of the high abundances also shown in fishery independent surveys.

The decrease observed in the DFO-industry **survey index** (Figures 6 and 7) since the all-time high of 2004 has leveled off in terms of overall biomass. A decrease in biomass (16%) was observed in Stratum 14 (Misaine) perhaps due to increased fishing pressure in this area in the last few years; however, this was offset by increases in other areas, resulting in little change from 2006. The DFO-industry survey index remains above the long-term average. Much of the biomass (~40%) remains concentrated in the Misaine area. The **spawning stock biomass** (female) also decreased from the 2004 record to about average in 2006-2007 for the 13-year survey series. It will probably remain at about this level in 2008 as the 2001 year-class continues to change sex, but it is likely to decrease subsequently as it continues to be targeted by the fishery and its natural mortality increases.

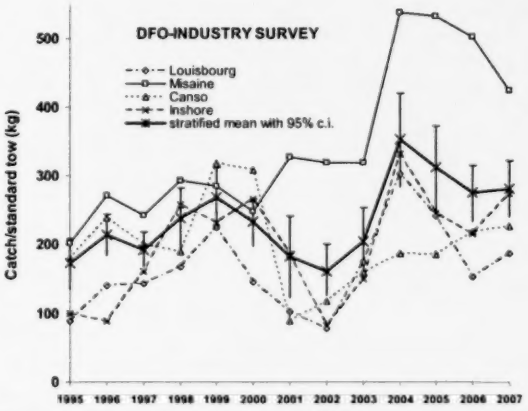

Figure 6. Commercial CPUE and survey abundance indices.

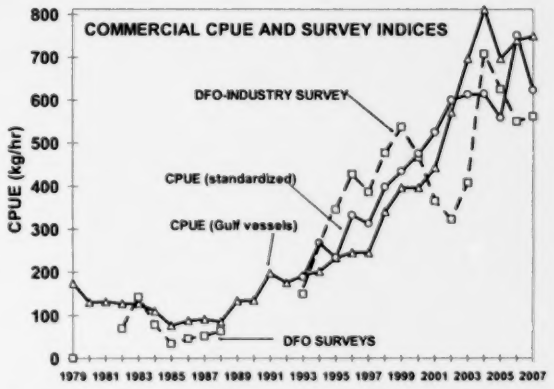

Figure 7. DFO-industry survey abundance indices by strata.

During the late 1990s, the fishery was supported by a strong group of year-classes (1993-1995), which reached the end of their life cycle in the early 2000s (Figure 5). Lower levels of recruitment in the mid 1990s led to a biomass decrease from 2000-2002 (Figure 7). Good recruitment mainly associated with the 2001 year-class (Figure 5) has led to the current high biomasses. This year-class continues to be strong in all areas and currently makes up most (~70%) of the total biomass. This is a concern because the unevenly distributed size/age structure could accentuate the pulsed recruitment pattern which appears to have developed, in addition to generally decreasing population stability. **Age 4 shrimp** in 2006 and 2007 (i.e., the 2002 and 2003 year-classes that entered or will be entering the fishery as females in 2007 and 2008) were not differentiated in the analysis, and their abundance appears to be very low. Ordinarily this would lead to rapid decreases in biomass and catch rates, however, due to slow growth, delayed sex change and possibly increased longevity, recruits to the female population in 2008 will continue to come from the large 2001 year-class. This should moderate decline of the fishable biomass but the degree to which this occurs will depend on natural mortality. The

abundance of age 2 shrimp has been declining since 2003 and was at a very low level in the 2007 survey trawl. Survey trawl and belly bag catches indicate that the 2002-2006 year-classes are considerably weaker than the 2001 year-class.

Total exploitation (11%) and **female exploitation** (14%) in 2007 remained at about 2006 levels, several percentage points below the long-term average. Exploitation was relatively evenly distributed throughout the stock area in 2005-2007 with no area receiving exceptionally high exploitation as has occurred on occasion previously. **Exploitation of small (<19mm) shrimp** increased to well above average in 2007, which is a conservation concern considering the lower recruitment of recent years.

Decreases in average **length at sex change** (L_t) in shrimp stocks may be associated with population downturns due to decreased population fecundity (smaller shrimp produce fewer eggs). On the Scotian Shelf, length at sex change has shown a decreasing trend since 1997 and is approaching the small sizes associated with the low population levels of the 1980s (Figure 8). **Maximum size** (L_{max}) has shown a similar decreasing trend but remains above the mean 1980s values (Figure 8). Some of the recent decrease in L_t may be associated with density dependent growth decreases in the 2001 year-class, but the observed long-term continuing decreasing trend in both indicators may be due to other causes such as environmental changes (e.g., temperature, Figure 9), and/or fishing, and is a concern.

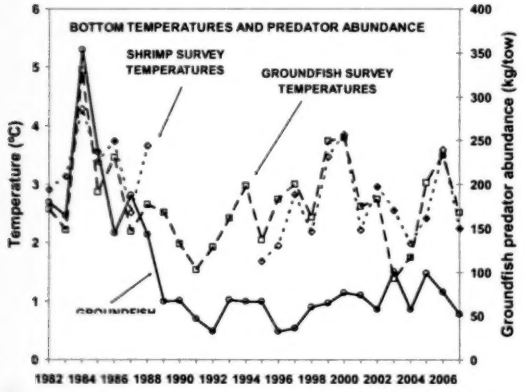
BOTTOM TEMPERATURES AND PREDATOR ABUNDANCE
SHRIMP SURVEY TEMPERATURES
GROUNDFISH SURVEY TEMPERATURES
Temperature (°C)
Groundfish predator abundance (kg/tow)
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006

Figure 8. Changes in mean size at sex transition and maximum size.

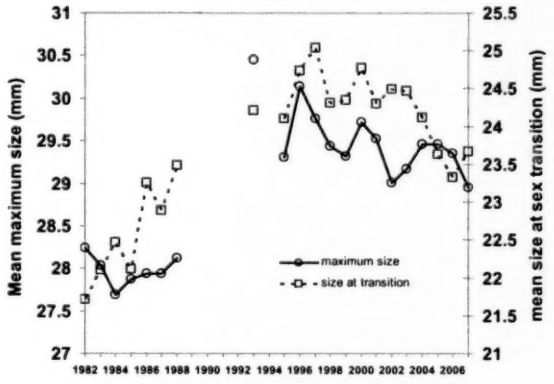
Mean maximum size (mm)
mean size at sex transition (mm)
maximum size
size at transition
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006

Figure 9. Bottom temperatures and predator abundance on the eastern Scotian Shelf shrimp grounds.

Regarding **ecosystem considerations**, feeding studies have shown that shrimp are important prey for many groundfish species and significant negative correlations between shrimp and groundfish abundance have been demonstrated from the Gulf of Maine to Greenland. Many groundfish stocks remain at low levels on the eastern Scotian Shelf and **natural mortality** due to predation is probably below the long-term average (Figure 9). Since shrimp abundance remains higher than the long-term average despite fishing, and because shrimp constitutes only a fraction of their diet, it seems unlikely that this fishery is impacting on the recovery of groundfish species by decreasing available prey. The introduction of the Nordmøre grate in 1991 reduced by-catch and allowed the fishery to expand to its present size. Analysis of observer and survey data from 1995-2006 confirms that by-catch weight remains very low and probably has little effect on the ecosystem. However, despite low by-catch by weight, most fish caught are small and some commercial species, particularly flatfish, are caught in relatively large numbers. The impact of these removals cannot presently be quantified because the sizes

of flatfish populations are not known. Conversely, the impact of predation by a relatively large shrimp stock on ichthyoplankton, including eggs of commercially important fish, is unknown.

For some northern shrimp stocks near the southern limits of the species' range, abundance is negatively correlated with water temperatures. On the Scotian Shelf, the population increase during the late 1980s may be associated with colder surface and bottom **water temperatures**. Large fluctuations in bottom water temperatures (Figure 9) may also be associated with the cyclical recruitment pattern experienced since the early 1990s (i.e., 1993-1995 and 2001 year-classes). The continued abundance of most cold water indicator species including shrimp, capelin, Greenland halibut and snow crab suggests that the regime shift which led to their success is enduring. Warmer surface and bottom water temperatures have been observed in recent years although temperatures were relatively cool in 2007- a continuing warming trend would be a concern for the shrimp stock.

Figure 10 provides a summary of 24 indicators related to the health of the eastern Scotian Shelf shrimp stock. Each indicator was assigned a color for every year there is data according to its percentile value in the series (i.e., >0.66 percentile = green ● or good, 0.66-0.33 = yellow ○ or intermediate and <0.33 = red ⊖ or bad). Indicators have been grouped into stock characteristics of abundance, production, fishing effects and ecosystem. Note that indicators are not weighted in terms of their importance, and the summary given at the top of the figure was determined as a simple average of individual indicators.

The overall summary turned green in 2007, after 2 years of yellow values; however, it was close to the green-yellow border. Characteristics have shown increasing yellow values since the generally favourable summaries of 2003-2004. Although 2 of the 4 characteristics were green in 2007 (an improvement from the single green characteristic the previous year), "fishing impact" in 2007 was the first red characteristic in 6 years. The "abundance" characteristic and its indicators were all favourable (green) including the two spatial indicators. Abundance and biomass remains high. These are not of immediate concern and support continued harvest at present levels for the immediate future (2008). However, the "production" characteristic remains yellow. These indicators remained unchanged except for maximum size and predator abundance, which exchanged yellow and green values. Low recruitment at age 2 and 4 continues to be the main concern in this area. Recruitment to the fishery and natural mortality of the 2001 year-class will determine the biomass and population trajectory in 2008 and beyond. As indicated above, fishing impacts changed from yellow to red, mainly due to a decrease in the size of females in the catch. The decreasing size of shrimp both in survey and commercial indicators continues to be a concern as it may be due to fishing and could be impacting on the reproductive capacity of the population. The ecosystem characteristic improved in 2007 (yellow to green) due to improvements in a number of indicators including surface and bottom water temperatures and cod and snow crab recruitment. Predator abundance, which may be considered an ecosystem indicator but is presently listed under production also improved. Consequently it seems that the environment continues to be generally favourable for shrimp on the eastern Scotian Shelf. The apparent downturn in recruitment in recent years may be due to density dependant factors, as suggested by stock recruitment relationships, unknown environmental factors, or fisheries impacts not considered, e.g., disturbance of mating behaviour. A new indicator filed under ecosystem characteristic (population age/length evenness) indicates that the population is now concentrated in fewer length categories than previously, which may contribute to less stable population dynamics and a pulsed recruitment pattern.

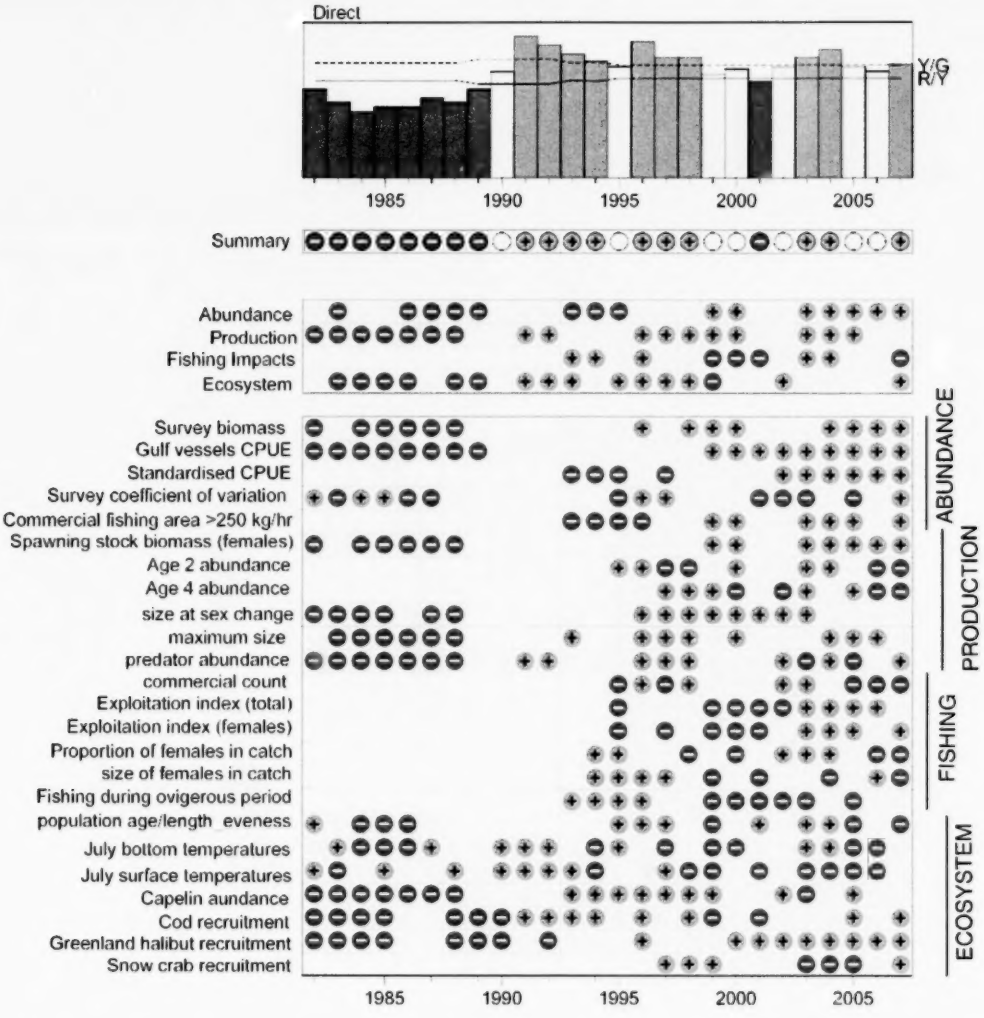

Figure 10. Traffic Light Analysis. Not all indicators in the Traffic Light table are discussed in the text. Please consult the current CSAS Research Document for a detailed description.

Sources of Uncertainty

DFO-industry shrimp survey results are associated with high variances. The accuracy of estimates can also be biased by temporal changes in availability during the survey period. In 2007 problems with NETMINDER distance sensors required use of historical average instead of actual wing spread data to calculate swept areas and abundance. Spatial analyses indicate that catch rates do not always represent overall abundance trends. There is considerable subjectivity associated with assigning modal groups to year-classes, consequently estimates of year-class strength, population numbers-at-age and projections using these analyses must be interpreted cautiously. Growth rates can decrease dramatically due to density dependence as happened with the strong 2001 year-class. Consequently, recruitment to the fishery will be delayed and spread over a longer time period. Uncertainties associated with the growth rate, sex change, natural mortality and longevity of this year-class preclude quantitative projections at this time. Unforeseen changes in the ecosystem e.g. predators, and the environment, e.g.,

temperature, together may lead to major regime shifts requiring radically different management strategies.

CONCLUSIONS AND ADVICE

Shrimp from the strong 2001 year-class began to change sex and recruit to the fishery as females in 2007 and will continue to do so in 2008, two years latter than usual due to slower density-dependant growth. Consequently, SSB should remain relatively high in 2008 but the 2009 SSB will depend on natural mortality and longevity of the 2001 year-class as it approaches the end of its life span. The 2002-2006 year-classes appear to be below average at this time, and biomass is expected to begin decreasing in 2009 as the 2001 year-class dies off. TAC reductions may be necessary after 2008. This year-class continues to grow slowly and commercial counts continued to increase in 2007. It will not achieve maximum size for several years and high counts will probably continue into 2008. With biomass expected to remain relatively high, the TACs of the last two years should be sustainable for one more year. However, it should be noted that the evenly distributed size/age classes observed earlier in this fishery (mid 1990s) has been replaced by a pulsed recruitment pattern due to exploitation, environmental influences or both, resulting in a less stable population more vulnerable to significant decreases in biomass. A continued precautionary approach, including annual assessments and a conservative harvest strategy, is recommended.

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FOR MORE INFORMATION

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